

N86-28408

TETHERED SATELLITE SYSTEM

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Thank you, Professor Guerriero.

Ivan, you mentioned the sometimes rather derisive remarks people make to you regarding tethers. When they make them to us, they ask how the tether is going, and we tell them we're hanging in there.

If you cannot see these charts clearly, they will be in the proceedings of the workshop and, in fact, the charts that I will submit for the workshop will go into more detail. We had to trim our presentation down. Also, if there are any questions, I'd be happy to answer those at any time during the proceedings.

If you don't mind, I'll look here and address the viewgraph rather than turn my back on you.

(Chart 1) The objective of the tethered satellite -- the TSS-1 -- is to develop the hardware, both on the satellite and a deployer side, for either a 20-kilometer or 100-kilometer deployment of the tether, either away from or toward the Earth. As you see, there are a variety of scientific interests; magnetometry, electrodynamics, and atmospheric science are of great interest.

(Charts 2-4) And I think, as has been discussed this morning, that the endeavor between the Italian government and the United States government in a joint development is very important. I'm not going to bore you with a detailed organization chart -- but I think it's very important for you to understand the relationship between the National Aeronautics and Space Administration and Italy's PSN/CNR organization in carrying out this program.

On the left, you see the responsibility of the United States and NASA in the development of the deployer, which fits in the orbiter cargo bay, and the integration of the satellite to the deployer and the conduct of the mission.

On the right, you see the responsibility of the Italian government, leading down to the contractors on both sides in this very important endeavor. On the United States side is Martin-Marietta Aerospace at Denver, which is responsible for hardware and integration for the United States' responsibilities. On the Italian side is Aeritalia, who is developing and designing the satellite.

Along with that are the scientific responsibilities between the two countries. All of the European science investigations are the responsibility of PSN and Aeritalia. And, on the United States side, are all non-European scientific investigations, the development of those instruments, and also the integration of all instruments on the deployer.

So the only reason I show this is to emphasize the very important relationships between the two countries.

(Chart 5) A few words about the first mission. The first mission is an engineering verification and electrodynamics science mission. That is, we must certainly prove without a doubt that we can deploy and retrieve a satellite safely. The first mission will be a 20-kilometer upward deployment with a conducting tether to demonstrate the electrodynamics science.

I will show you the timeline in a few moments. It's nominally a 38-hour mission at a 160 nautical mile Shuttle orbit.

The deployer design for all missions is to be able to fly a conducting or non-conducting tether up to a hundred kilometers. We have a full length boom of 12-meters to extend the satellite out away from the deployer prior to deployment.

The satellite itself is a 1.6 meter, 500-kilogram satellite, with lateral and in-line tether satellite thrusters, to maintain control at the close-in distances. That is the first TSS flight on which we are proceeding.

(Chart 6) This is the configuration that is under development at this point in time. This is the forward direction in flight. We have the basic Spacelab pallet with the deployer and satellite mounted on the pallet. We have a structure called the Mission Peculiar Equipment Support Structure (MPESS), which is nothing more than a structure to support scientific payloads. The advantage of this is to be able to put most of the scientific instruments on a separate structure from the deployer to simplify reflight. It makes a much simpler integration job.

(Chart 13) For those who may be interested in the configuration of the tether that we have to date — this may not be the final flight configuration, but it's very close to it.

The tether itself has a Nomex core around which is wrapped a copper conductor equivalent to a 24-gauge conductor, with an insulator wrapped around that. And then the load-carrying member is Kevlar 29. It has about a 400-lb. strength capability. And then around that is woven a Nomex jacket to protect against monatomic oxygen effects, which we have noticed on past Shuttle flights.

The diameter is about two millimeters. On the first mission, since only 20 kilometers are reeled out, the loads on the tether itself will be very small.

If you would care to look at this after the session or any time this week, I would be happy to show it to you.

(Chart 14) I won't go into this in a lot of detail because I don't know a lot of the details about it. The thing I wanted to point out is, I personally came into the project with people telling me it's a very simple, straightforward easy-to-accomplish, inexpensive project. The more we get into it, the more complex it is. I had one individual tell me that the communication links between a deployed satellite with which you still have control, the orbiter, its communications system, the enhanced pallet, which has a computer system on the pallet that talks to the deployer as well as the pallet, as well as the scientific instru-

ments, the communications links -- oh, pardon me -- and the S-band communication link, the Ku-band man tracking it all the time; he felt the communication loops between tether were more complex than Spacelab 1. And Spacelab 1 was very complex.

We have a lot of organizational interfaces, and anytime one has organizational interfaces, trying to build a payload or fly a mission, it's very complex, and the communication between us must always be very clear. That's one of our -- I think -- our greater challenges.

So we have the orbiter with the pallet. We will use the Marshall Space Flight Center -- Payload Operations Control Center -- as well as the Johnson Mission Control Center. Johnson will be responsible and have control of the total mission.

This is the data display control unit. That is what is called the DDCU computer for what I'll call it the SMART pallet. We will do some science processing with that.

And these items here on the flight deck, which will be under control of the Payload Mission specialists.

So I think the communication loops are very complex.

(Chart 15) As I said, for the mission operations, we will have use of the Huntsville Operations Support Center, which will do the engineering support for the deployer, and the Spacelab pallet. It is the engineering support to Houston which will conduct the mission. We will use the Payload Operations Control Center at Marshall to do the scientific support. We will also use, that is, plan on using, the Payload Crew Training Complex, which was used on the Spacelab missions for training the onboard crew for operations.

We have recently established a Flight Operations Working Group to start that endeavor. And we are just beginning to get fairly deep into the integration of JSC on the conduct of the mission and the payload operations functions.

(Chart 16) I'll say a little bit about the timeline for the total 38 hours. This has been modified, or probably will be modified, somewhat. We had the second investigators working group meeting in Italy last week, and they had some recommendations that change the timeline.

But, in essence, the deployment will take about ten hours, the reason being, at this point in the baseline, that we have two stops. We would like to deploy out to about ten kilometers, stop, spin the satellite up, take science data for about an hour and a half, and then de-spin it. And then go on to station at 20 kilometers for about 18 to 20 hours.

I show a crew sleep cycle there, although I don't really believe that will ever happen. I can't imagine a satellite being deployed out on the station and people sleeping with the satellite out, but that's in the timeline.

For planning purposes, I think that's a good idea, because we should, I believe, baseline ourselves such that we can control the science from the ground during that time period with the crew in the monitoring mode. I believe that's the way they will end up with it.

And then, at the end of that 31 hours total, would be a retrieval. At this point in time, we see no reason to stop on the way back in. It would take away from the time on-station, so our plan right now is to start the retrieval and pull it straight on in at the end of the 38 hours.

(Chart 17) I'll say a few words about the science that has been selected, and then just leave it at that.

The science is split between the satellite, that is the science that goes on the satellite, and that which goes on the deployer. Marino Dobrowolny has been selected to do the electrodynamic tether effects, Dr. Nobie Stone at Marshall Space Flight Center on the satellite, and Professor Mariani at the University of Rome with the magnetic fields. This is orbiter instrumentation. That's really science instruments that go on the deployer. Peter Banks at Stanford with his experiment. That has been changed to Drobot, I believe, on the plasma coupling studies. Gullahorn at the SAO, and Bergamaschi at Padua, and Bob Estes on the electronic emissions.

That's all the charts I had. The status we're in right now; we're coming up on a critical design review for the deployer in about a month. In fact, it's already started. And that means that we have about 90 percent of the design complete on the deployer.

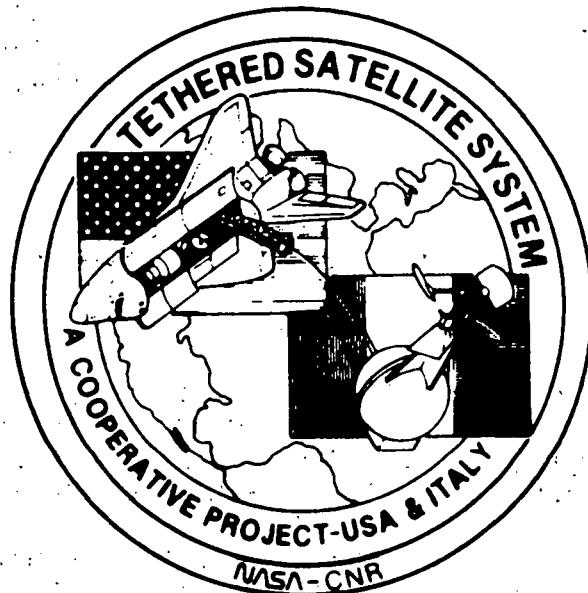
And we are into the first parts of structures manufacturing, so we are in a position now of cutting hardware for this.

The first flight is scheduled for September 1988 -- and that may seem a long time away, but it will be here before we know it.

Thank you very much.

## TETHERED SATELLITE SYSTEM

### PROJECT OVERVIEW



APPLICATIONS OF TETHERS IN SPACE WORKSHOP  
VENICE, ITALY  
OCTOBER 15-17, 1985

JAMES M. SISSON  
NASA/MSFC

ORGANIZATION: FA31	MARSHALL SPACE FLIGHT CENTER <b>TETHERED SATELLITE SYSTEM</b>	NAME: J. SISSON
CHART NO.: 3546-85		DATE: OCTOBER 1985

## OBJECTIVES

### ● SYSTEMS

DEVELOP A REUSABLE SYSTEM TO ENABLE A VARIETY OF SCIENTIFIC INVESTIGATIONS TO BE ACCOMPLISHED FROM THE SHUTTLE, CONSIDERING:

- USE OF A TETHERED SYSTEM WITH MANUAL/AUTOMATED CONTROL
- DEPLOYMENT OF A SATELLITE TOWARD OR AWAY FROM THE EARTH, UP TO 100 KM
- CONDUCTING OR NON-CONDUCTING TETHER

### ● SCIENTIFIC

PERFORM EXPERIMENTS AND SCIENTIFIC INVESTIGATIONS USING THE TETHER SYSTEM FOR APPLICATIONS SUCH AS:

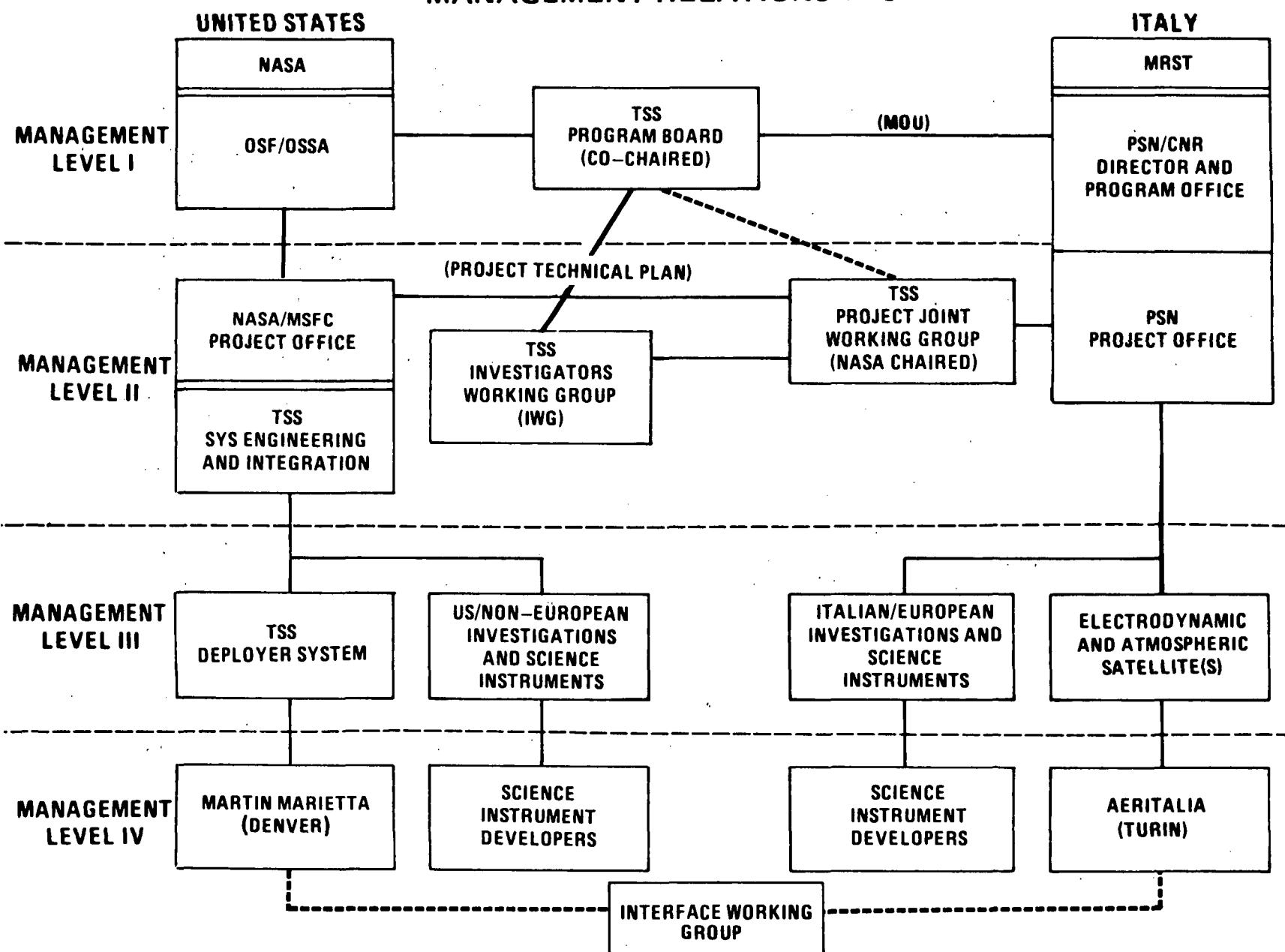
- MAGNETOMETRY
- ELECTRODYNAMICS
- ATMOSPHERIC SCIENCE
- CHEMICAL RELEASE
- OTHER

### ● PROGRAMMATIC

IMPLEMENT PROGRAM AS A COOPERATIVE U.S./ITALIAN ACTIVITY

- US DEPLOYER DEVELOPMENT
- ITALIAN SATELLITE DEVELOPMENT
- US OVERALL SYSTEM INTEGRATION
- JOINT US/ITALIAN SCIENCE DEVELOPMENT/INTEGRATION

# TETHERED SATELLITE SYSTEM MANAGEMENT RELATIONSHIPS



ORGANIZATION: TSS PROJECT OFFICE	MARSHALL SPACE FLIGHT CENTER  <b>TETHERED SATELLITE SYSTEM PROJECT OVERVIEW</b>	NAME: J. SISSON
CHART NO.: 2974-85		DATE: OCTOBER 1985

## TSS PROGRAM RESPONSIBILITIES

### UNITED STATES

#### NASA HEADQUARTERS

- PROGRAM MANAGER (OSF)
- PROGRAM SCIENTIST (OSSA)

#### TSS PROJECT OFFICE

- PROJECT MANAGER
- MISSION MANAGER
- TSS SYSTEM ENGINEERING & INTEGRATION
- TSS DEPLOYER/SYSTEM DEVELOPMENT
- CHANGE CONTROL BOARD, LEVEL II, III
- CONTRACT MANAGEMENT/EVALUATION
- LAUNCH/MISSION OPS. PLANNING/SUPPORT
- SCIENCE INSTRUMENT DEVELOPMENT
- CORE EQUIPMENT DEVELOPMENT
- SCIENCE/CORE EQUIPMENT INTEGRATION

#### MARTIN MARIETTA AEROSPACE

- OVERALL SE&I SUPPORT/IMPLEMENTATION
- DEPLOYER SYSTEM DEVELOPMENT
- EXPERIMENT DEVELOPMENT/INTEGRATION
- LAUNCH/MISSION OPERATIONS SUPPORT

### ITALY

#### NATIONAL RESEARCH COUNCIL (CNR) NATIONAL SPACE PLAN (PSN)

- PROGRAM/PROJECT MANAGER
- PROGRAM/PROJECT SCIENTIST
- TSS SATELLITE DEVELOPMENT
- SCIENCE INSTRUMENT DEVELOPMENT
- CORE EQUIPMENT DEVELOPMENT
- SATELLITE SCIENCE/CORE INTEG.
- GROUND/FLIGHT OPS. SUPPORT
- LAUNCH/MISSIONS OPS. SUPPORT

#### AERITALIA, SUB-CONTRACTORS

- SATELLITE SYSTEM DEVELOPMENT
- EXPERIMENT DEVELOPMENT/INTEG.
- LAUNCH/MISSION OPS. SUPPORT

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CHART NO.: <b>2975-85</b>		DATE. <b>OCTOBER 1985</b>

## TSS PROGRAM RESPONSIBILITIES, UNITED STATES (CONT'D)

### MARSHALL SPACE FLIGHT CENTER

#### SCIENCE & ENGINEERING

- PROJECT ENGINEER
- PROJECT SCIENTIST
- LABORATORY DISCIPLINE SUPPORT
  - COUPLED DYNAMICS, LOADS
  - FRACTURE MECHANICS, MUA'S
  - EEE PARTS, ETC. ETC.
- DYNAMICS WORKING GROUP
- C&DH WORKING GROUP
- HOSC, MSFC POCC, PCTC
- FLIGHT OPERATIONS WORKING GROUP
- GROUND OPERATIONS WORKING GROUP
- DESIGN REVIEW SUPPORT
- PERFORMANCE EVALUATION SUPPORT

#### SPACELAB PROGRAM OFFICE

- A & B LEVEL ICD
- ENHANCED MDM PALLET, MMESS
- ENGINEERING MODEL PALLET
- THERMAL ANALYSIS AND DESIGN
- STD. & SPECIAL COLDPLATES
- UTILITIES

#### SAFETY OFFICE

- SYSTEM SAFETY

#### ADMINISTRATION & PROGRAM SUPPORT

- PROCUREMENT
- PERSONNEL, OTHER

### OTHER CENTERS

#### JOHNSON SPACE CENTER

- FLIGHT OPERATIONS
- CREW TRAINING
- PAYLOAD INTEGRATION PLAN
- SHUTTLE ENGINEERING SIMULATOR
- FLT. OPS. SAFETY REVIEW BOARD
- FLIGHT DATA FILE

#### KENNEDY SPACE CENTER

- LEVEL IV INTEGRATION
- ASSEMBLY & END-TO-END TESTS
- GROUND/LAUNCH OPERATIONS
- DEINTEGRATION, PAD CHANGE-OUT
- GROUND OPS. SAFETY REVIEW BOARD

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CHART NO.: 2973-85		DATE: OCTOBER 1985

## INITIAL FLIGHT

- MISSION: ENGINEERING VERIFICATION & ELECTRODYNAMIC SCIENCE
- LAUNCH DATE: SEPTEMBER 1988
- CHARACTERISTICS:
  - 20 KM UPWARD DEPLOYED SATELLITE
  - CONDUCTING TETHER
  - 38 HOUR MISSION
  - 160 NM SHUTTLE ORBIT
- DEPLOYER & SATELLITE WILL BE DESIGNED TO "FULL CAPABILITY" SPECIFICATIONS, IN TERMS OF:
  - CONDUCTING OR NON-CONDUCTING TETHER
  - UP TO 100 KM DEPLOYMENT
  - FULLY INSULATED/ISOLATED DEPLOYER MECHANISM
  - FULL LENGTH/STRENGTH BOOM
  - 1.6 METER, 500 KG SATELLITE (INCL. INSTRUMENTS)
  - LATERAL AND TETHER-ALIGNED SATELLITE THRUSTERS

ORGANIZATION:  
FA31  
CHART NO.:  
3548-85

MARSHALL SPACE FLIGHT CENTER

NAME:

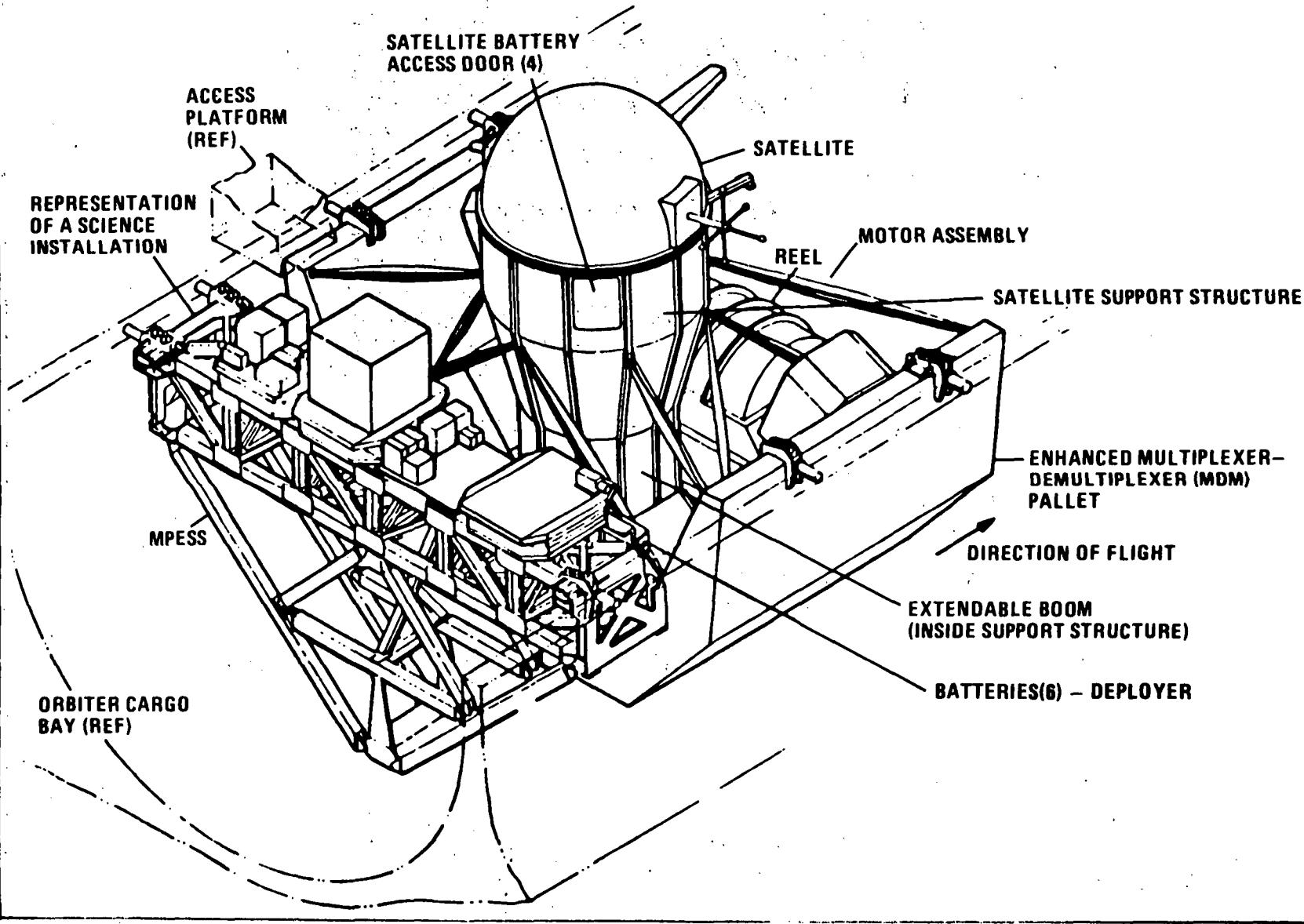
JAMES M. SISSON

DATE:

OCTOBER 1985

## TETHERED SATELLITE SYSTEM MISSION 1 CONFIGURATION

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● SPACE TRANSPORTATION SYSTEM (STS)

- LAUNCH/ON-ORBIT PLATFORM/LANDING
- UPLINK COMMAND/DOWN LINK DATA/CREW COMMUNICATIONS
- 28.5 DEGREE INCLINATION
- -Z LOCAL VERTICAL ATTITUDE (TSS OPERATIONS)
- 297 KILOMETER ALTITUDE (NEAR CIRCULAR ORBIT)
- KU-BAND RADAR TRACKING OF SATELLITE

● ENHANCED MULTIPLEXER-DEMULITPLEXER (MDM) PALLET

- STRUCTURAL
  - HARD POINT MOUNTS
  - EQUIPMENT MOUNTING PANELS
- ELECTRICAL
  - MAIN BUS
  - AUXILIARY BUS
  - POWER DISTRIBUTION/CONTROL
- THERMAL
  - FREON COOLANT LOOP
  - COLD PLATES
- COMMAND AND DATA MANAGEMENT
  - UPLINK COMMAND PROCESSING
  - DATA MULTIPLEXING INTERFACE TO STS
  - DATA DISPLAY AND CONTROL UNIT (DDCU)
  - SPECIAL DATA PROCESSING

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CHART NO.: 3550-85		DATE: <b>OCTOBER 1985</b>

**● MISSION PECULIAR EQUIPMENT SUPPORT STRUCTURE (MPESS)**

- STRUCTURAL
  - SCIENCE
  - DEPLOYER BATTERIES
- ELECTRICAL
  - RECEIVE POWER FROM PALLET
  - DISTRIBUTE POWER TO SCIENCE
  - ROUTE DEPLOYER BATTERY POWER TO PALLET
- THERMAL
  - FREON LOOP INTERFACE TO PALLET
  - COLD PLATES
- COMMAND AND DATA MANAGEMENT
  - ROUTE COMMANDS TO SCIENCE
  - ROUTE DATA FROM SCIENCE/DEPLOYER BATTERIES

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CHART NO.: 3554-85		DATE: OCTOBER 1985

● **DEPLOYER**

- REEL/MOTOR ASSEMBLY
  - REEL CAPACITY
    - 20 KILOMETERS (CONDUCTING TETHER)
    - 100 KILOMETERS (NON-CONDUCTING TETHER)
  - REEL MOTOR TORQUE —  $\pm$  54.5 NEWTON-METERS (~ 40 FT-LBS)
  - REEL MECHANICAL BRAKE
  - REEL ELECTRO-MECHANICAL BRAKE (MOTOR-GENERATOR/LOAD BANK)
  - LEVEL WIND DEVICE
  - REEL SPEED — 0 TO 600 RPM
  - CONTROLLED BY MOTOR CONTROL ASSEMBLY
  - ELECTRICALLY ISOLATED INTERFACE TO TETHER CONDUCTOR
- DATA ACQUISITION AND CONTROL ASSEMBLY
  - ACCEPT/PROCESS UPLINK COMMANDS (2 KBPS)
    - DEPLOYER
    - ATTACHED SATELLITE
  - COLLECT/MULTIPLEX DOWN LINK DATA (16 KBPS)
    - DEPLOYER
    - ATTACHED SATELLITE

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● DEPLOYER (CONTINUED)

- DATA ACQUISITION AND CONTROL ASSEMBLY (CONTINUED)
  - CONTROL TETHER DURING DEPLOY/RETREIVE/ON STATION
    - SOFTWARE CONTROLLED
    - ALGORITHMS
    - DEPLOYER SENSORS
    - INTERMEDIATE STOP CAPABILITY
  - CONTROL/MONITOR BOOM EXTEND/RETRACT
- SATELLITE SUPPORT STRUCTURE
  - SUPPORT 500 KILOGRAM SATELLITE
  - SATELLITE ROTATION  $\pm 185^{\circ}$
  - SATELLITE ALIGNMENT GUIDE
  - 6 SATELLITE LATCHES
  - CONTAINS BOOM
  - 2 SATELLITE UMBILICALS (NON-RECONNECTABLE)
    - 1 SEPARATES AT 60 CM BOOM MOVEMENT
    - 1 SEPARATES AT FULL BOOM EXTENSION
  - SPRINGS/GUIDE RAILS FOR BOOM JETTISON
  - BOOM EJECTION PYROTECHNICS

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● DEPLOYER (CONTINUED)

— TETHER CONTROL

- TENSION (INBOARD) – 0 TO 100 NEWTONS (EDM)  
— 0 TO 400 NEWTONS (ATM)
- TENSION (OUTBOARD) – 0 TO 15 NEWTONS
- LENGTH MEASUREMENT – 0 TO 22 KILOMETERS
- RATE – +12 METERS/SEC TO – 12 METERS/SEC
- UPPER TETHER CONTROL MECHANISM (TOP OF BOOM)
- LOWER TETHER CONTROL MECHANISM (BOTTOM OF BOOM)
- UPPER TETHER CUTTER
- LOWER TETHER CUTTER

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● DEPLOYER (CONTINUED)

- BOOM
  - LENGTH – 12 METERS
  - EXTENDABLE/RETRACTABLE
  - ARTICULATED LONGERON DESIGN
  - 60 CM STOP CAPABILITY
  - ENCLOSES SATELLITE UMBILICALS
  - JETTISONABLE
  - REDUNDANT MOTOR DRIVES
- TETHER
  - GENERAL CORE – MULTI-STRAND NOMEX, 1200 DENIER
  - CONDUCTOR – 10 STRANDS # 34 AWG TIN COATED COPPER, HIGH HELIX ANGLE (5 TURNS/IN)
  - CONDUCTOR INSULATION – EXTRUDED TEFLON FEP
  - LOAD MEMBER – BRAIDED KEVLAR # 29 (YELLOW) 400 LB BREAKSTRENGTH
  - PROTECTIVE OUTER JACKET – BRAIDED NOMEX (WHITE)

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NAME:

J. SISSON

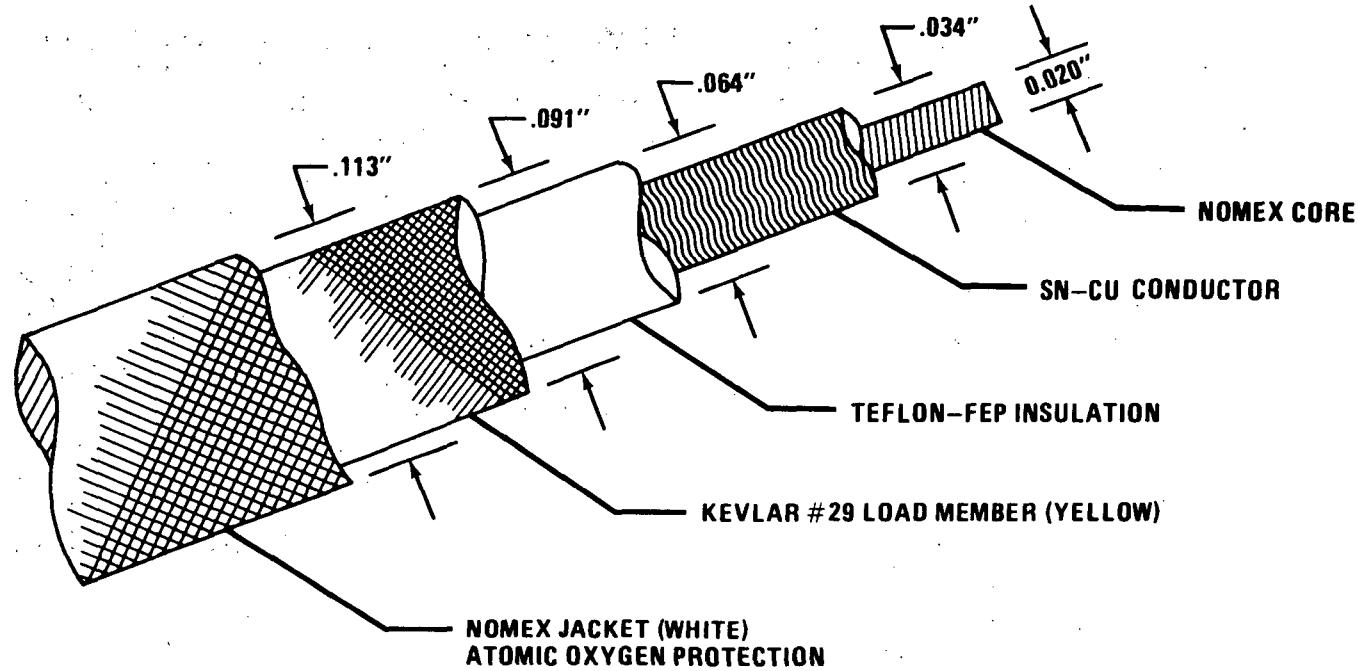
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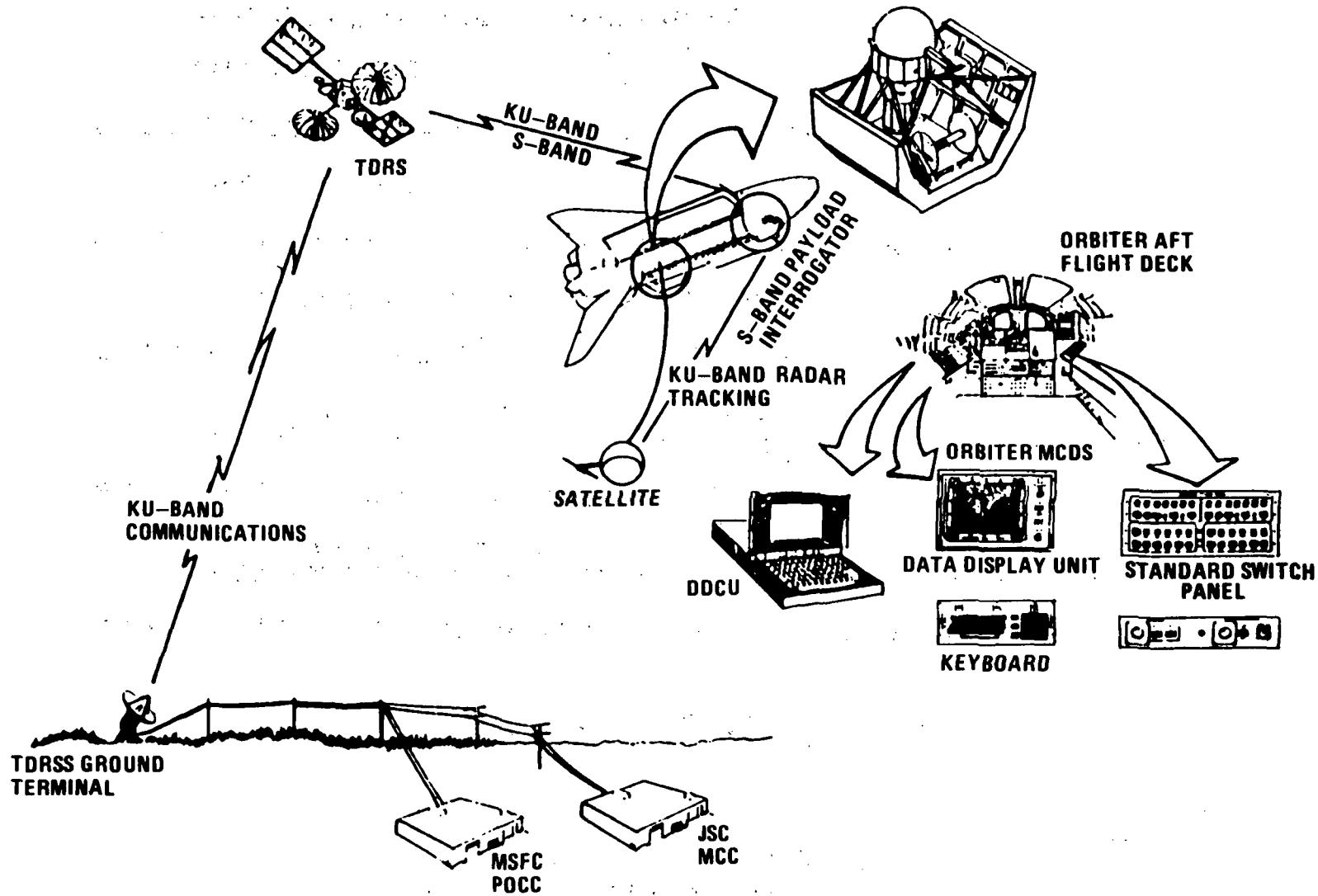
**TETHERED SATELLITE SYSTEM**

DATE:

OCTOBER 1985

**FIRST MISSION (TSS) CONDUCTING TETHER CONFIGURATION**

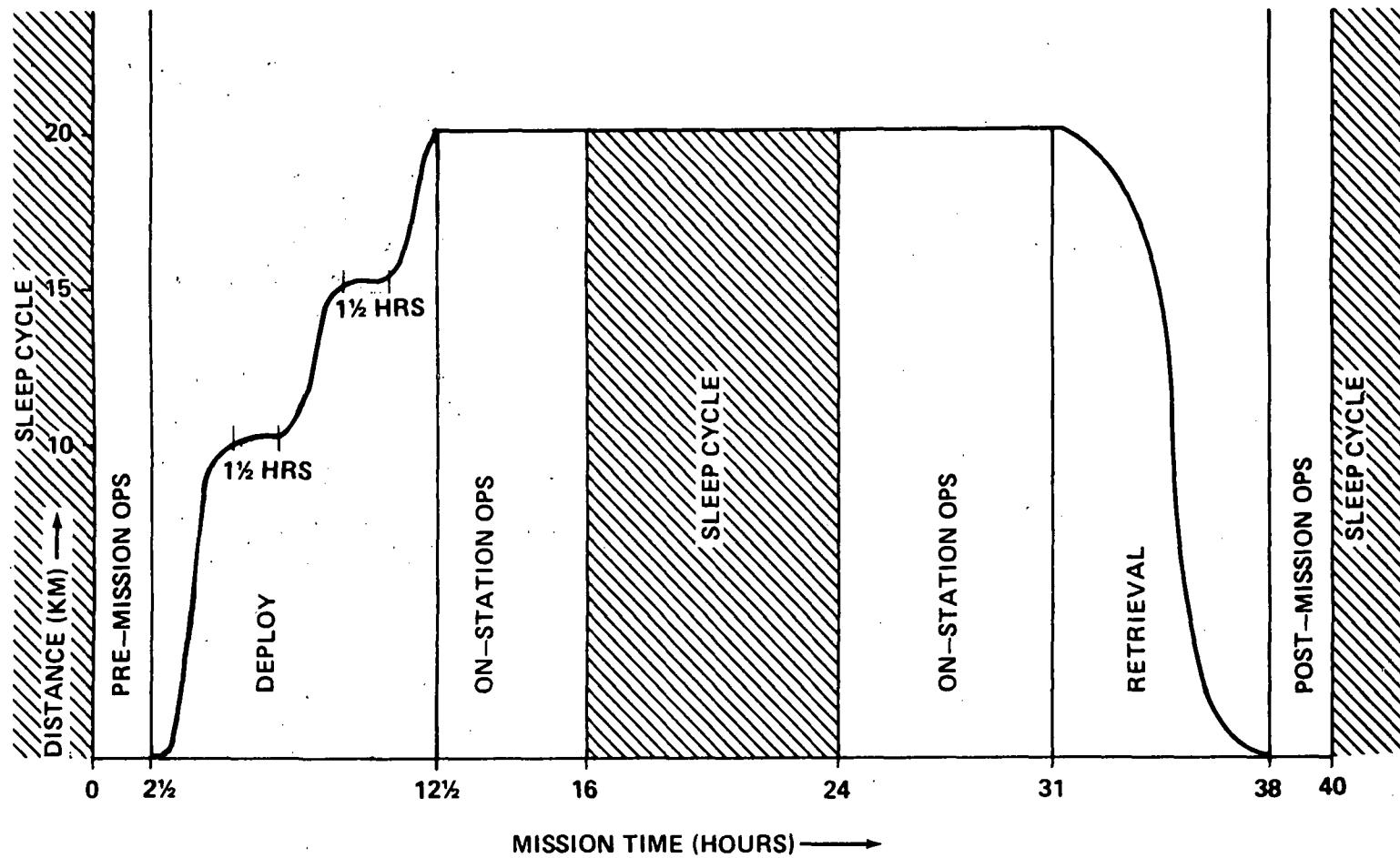
## DESIGN OVERVIEW – TSS/ORBITER/GROUND INTERFACES



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CHART NO.: 2926-85		DATE: OCTOBER 1985

## MISSION OPERATIONS

- WILL USE HUNTSVILLE OPERATIONS SUPPORT CENTER (HOSC)
  - PROVIDE ENGINEERING SUPPORT FOR THE SATELLITE, DEPLOYER, AND THE ENHANCED MDM PALLET (EMP) SYSTEMS
- WILL USE MSFC PAYLOAD OPERATIONS SUPPORT CENTER (POCC)
  - PROVIDE SUPPORT TO SATELLITE SCIENCE, SATELLITE CORE EQUIPMENT, DEPLOYER SCIENCE AND DEPLOYER CORE EQUIPMENT
- WILL USE MSFC PAYLOAD CREW TRAINING COMPLEX (PCTC)
  - PROVIDE TRAINING FOR ON-BOARD CREW
- FLIGHT OPERATIONS WORKING GROUP (FOWG) ESTABLISHED
  - CHAIRED BY S&E
- PAYLOAD OPERATIONS WORKING GROUP (POWG) ESTABLISHED
  - CHAIRED BY JSC
  - SUPPORT DEPLOYMENT AND RETRIEVAL
  - SUPPORT DETACHED SATELLITE OPERATIONS

TSS-1 TIMELINE

ORGANIZATION: FA31	MARSHALL SPACE FLIGHT CENTER <b>TETHERED SATELLITE SYSTEM PRINCIPAL INVESTIGATION SCIENCE</b>	NAME: J. SISSON
CHART NO.: 2885-85		DATE: OCTOBER 1985

● SATELLITE INSTRUMENTATION

● ELECTRODYNAMIC TETHER EFFECTS – DOBROWOLNY (CNR)

- 3 AXIS DIPOLES
- A. C. ELECTRIC FIELDS & ELECTROSTATIC WAVES
- 2 AXIS SEARCH COILS
- A. C. MAGNETIC FIELDS
- (2) LANGMUIR PROBES
- $e^-$  DENSITY,  $e^-$  ENERGY, POTENTIAL DISTRIBUTION

● PLASMA ELECTRODYNAMICS – STONE (MSFC)

- DIFFERENTIAL ION FLUX PROBE
- ION ENERGY TEMPERATURE AND DENSITY VS INCIDENCE ANGLE
- (8) SOFT PARTICLE ENERGY SPECTROMETER
- CHARGED PARTICLE ENERGY DISTRIBUTION AND SPACE POTENTIAL
- TRIAXIAL FLUXGATE MAGNETOMETER
- VECTOR MAGNETIC FIELDS

● MAGNETIC FIELDS – MARIANI (U. ROME)

- TRIAXIAL FLUXGATE MAGNETOMETER

● ORBITER INSTRUMENTATION

● VEHICLE CHARGING AND POTENTIAL – BANKS (STANFORD)

- (2) SPOT CHARGE AND CURRENT PROBES
- LOCAL CURRENT AND POTENTIAL
- SPHERICAL LANGMUIR PROBE
- VEHICLE POTENTIAL, ION DENSITY AND
- FAST PULSE ELECTRON GUN
- TEMPERATURE

● ELECTRODYNAMIC THEORY

● PLASMA COUPLING STUDIES – PAPADOPOLIS (SAI)

● TETHER DYNAMICS

● DYNAMIC NOISE STUDIES – GULLAHORN (SAO)  
● DYNAMIC NOISE STUDIES – BERGAMASCHI (PADOVA – ITALY)

● GROUND BASED OBSERVATIONS

● EM EMISSIONS – ESTES (SAO)

- ELF RECEIVERS
- DETECT TETHER GENERATED EMISSIONS AT ELF
- MAGNETOMETERS
- DETECT TETHER GENERATED EMISSIONS AT ULF